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OFF-SITE RADIOLOGICAL SURVEILLANCE PROGRAM FOR PROJECT GASBUGGY

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by
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Consumer Protection and Environmental Health Service

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ABSTRACT

Project Gasbuggy, an experiment to stimulate gas recovery by nuclear means, was conducted on December 10, 1967, as part of the USAEC Plowshare Program. The U. S. PHS by Memorandum of Agreement with the USAEC is responsible for a comprehensive Off-Site Radiological Safety Program. The procedures used and the data obtained in connection with this Project are summarized. Surveillance of the El Paso natural gas producing wells near the Gasbuggy experiment was conducted to insure that radioactive contaminated gas is not present.

OFF-SITE RADIOLOGICAL SURVEILLANCE PROGRAM FOR PROJECT GASBUGGY

INTRODUCTION

On Sunday, December 10, 1967, at 12:30:00 Mountain Standard Time, at a location 55 air miles east of Farmington, New Mexico, a 26-kiloton thermonuclear explosive was detonated 4,240 feet below the surface of the Carson National Forest. (Figures 1 and 3). The event, Project Gasbuggy, was the first joint government-industry experiment in the U.S. Atomic Energy Commission's Plowshare Program. The joint sponsors, in addition to the AEC, were the U.S. Department of Interior (Bureau of Mines) and the El Paso Natural Gas Company.

Among the main objectives of the experiment were to determine if nuclear explosions can increase the production rate and ultimate recovery of natural gas from low permeability gas formations. Some flow tests, as well as gas quality analyses, have been made of the Project Gasbuggy well by the project participants; however, until more extensive flow tests are made in 1969, conclusive information will not be available as to the degree of success of the experiment.

Several factors affecting the safety of the project included: the depth of the device, the proximity of an aquifer to the detonation, and the location of gas production wells with respect to ground zero. The device was placed at a depth of 4,240 feet in the Lewis Shale formation in the San Juan Basin. This depth is about 40 feet below the bottom of the gasbearing Pictured Cliffs formation (Figure 2). At this depth, the device was considered to be overburied by safety standards in use at the Nevada Test Site. (A 26-kt device would be considered safely emplaced at NTS at a depth of approximately 1,200 feet). The lowest water bearing formation is the Ojo Alamo Sandstone which is located from 3,475 to 3,650 feet below the surface at the site. The nearest aquifer, therefore, is approximately 590 feet above the shot point. The site chosen for the project is on land leased by El Paso Natural Gas Company; the only wells in the area belong to them and the closest production

well is 3,400 feet from ground zero. As a precaution, all producing wells within approximately a five-mile radius of ground zero were physically separated from the gas transmission system. Nevertheless, the AEC hypothesized all possible failure modes which could release radioactivity into the atmosphere, into ground water, or, into the natural gas production system. Although these failure modes were considered highly unlikely, the AEC authorized a comprehensive radiological safety program for Project Gasbuggy.

OFF-SITE RADIOLOGICAL SAFETY PROGRAM

This report summarizes the Off-Site Radiological Safety Program for Project Gasbuggy as conducted by the Southwestern Radiological Health Laboratory (SWRHL) of the National Center for Radiological Health. In accordance with a Memorandum of Understanding between the U.S. Atomic Energy Commission and the Public Health Service, the SWRHL is responsible for conducting off-site radiological safety programs for all U.S. nuclear tests.

A surveillance program was established by SWRHL to collect and analyze environmental samples before and after the nuclear detonation, to document any possible release of radioactivity to the off-site area, and to be prepared to handle emergency procedures to insure protection of the public health had an unforeseen accident occurred. Samples provided data on air, milk, water, natural gas, and natural radiation levels in the area surrounding the site.

The off-site surveillance program was divided into the following three periods:

1. The pre-shot preparations - June 1, 1967 to Detonation (1230 MST, December 10, 1967).
2. The post-shot period, including the redrill of the emplacement hole (GB-ER) - December 10, 1967, to January 20, 1968.
3. The redrill of the Gasbuggy-2 (GB-2R, one of the two exploratory wells drilled before the emplacement hole) and subsequent natural gas flaring operations from GB-ER and GB-2R - June 13 to July 22, 1968.

Environmental samples were collected pre-shot to establish background radioactivity levels. Following the completion of the post-shot period and again after the GB-2R redrill period, samples were collected to form a comparison with the background data.

The SWRHL pre-shot preparations in the Project Gasbuggy area began in June 1967. During the summer of 1967, a census was taken of all people and milk cows within 100 miles of the Gasbuggy site, in addition, all mining and tunneling operations within 50 miles were located. As the census information was collected, personnel distributed printed information explaining the nature of the experiment and answered questions regarding their activities. The Community Relations Program was intensified during later periods when the SWRHL Project Officer and state health department officials visited local officials in surrounding communities. The initial environmental sampling was begun in August 1967. The dosimetry program began in October 1967. Medical and veterinarian activities began during the pre-shot period when the respective officers made visits to various state and local officials; these activities continued throughout the drill-back of GB-ER. Approximately thirty people from the SWRHL and the health departments of New Mexico and Colorado were assigned to the SWRHL Gasbuggy surveillance program on December 1, 1967. A short training course was given to state personnel on procedures to be used and all personnel were oriented with the area around the site.

At shot time, SWRHL had thirty-three personnel on station, including monitoring teams in two aircraft orbiting the site. The number of people was reduced in mid-December to five who remained throughout the redrill of GB-ER.

The GB-2R redrill operations began in mid-June 1968, and were completed by mid-July 1968. They included the redrill of GB-2R and flow testing (flaring) of natural gas from the GB-ER well for fifteen days. The Project Officer was on-site for these operations. Staff previously assigned to the project were on standby at SWRHL in the event additional field personnel were needed.

AIR SURVEILLANCE

The Project Gasbuggy Air Surveillance Network collected daily samples pre-shot and during the immediate post-shot period at thirty-five locations surrounding the Gasbuggy site. Six of these stations were part of the SWRHL Air Surveillance Network (ASN) and two were activated ASN Standby Stations. The remaining twenty-seven stations were established specifically for the project. The Gasbuggy network is shown in Figure 3.

Air sampling stations were equipped with Gelman Tempest air samplers using a Gast Model 1550 positive displacement pump. The filter system used a four-inch diameter Whatman 541 filter in series with a four-inch MSA* activated charcoal cartridge.

The Gasbuggy Network began operations on November 27, 1967, and continued through December 13, 1967. The nine stations nearest the site were operated throughout the GB-ER drill-back period until January 19, 1968. A total of 1120 sets of samples were collected. In mid-April 1968, sixteen of the twenty-eight special stations were discontinued, leaving eleven on standby. These stations were operated from June 30, 1968, to July 18, 1968. A total of 200 sets of samples were collected during this period.

All filters and charcoal cartridges were mailed directly to SWRHL for analysis. The filters were analyzed for beta activity upon arrival at the laboratory and again on the fifth and twelfth day after collection. If the initial beta count indicated an activity concentration of more than one pico-curie per cubic meter, or if the five-day count was more than 150 counts per minute above background, the filter was gamma scanned. The charcoal cartridge was gross gamma counted upon arrival and, if the count was greater than 500 counts per minute, the filter and cartridge were gamma scanned. These control limits were based on normal background concentrations.

---

*MSA - Mine Safety Appliance, part 46727 charcoal cartridge. The cartridge is an organic vapor type cartridge containing stable iodine to improve the organic iodine retention capability.

The air sampling results for each of the three periods is summarized in Table I. The post-shot period is further divided into two periods since levels of radioactivity in air were generally higher across the United States during the last five days of December 1967.[1]

MILK SURVEILLANCE

Milk Sampling coverage was provided by the Gasbuggy Milk Surveillance Network during the pre-shot and operational periods. Twenty-two stations were sampled; thirteen represented family milk cows and nine were Grade A dairies. The station locations are shown in Figure 4.

Samples were collected at each location during the following periods: July 30 to August 1, 1967; September 4-7, 1967; October 20-25, 1967; and January 19-20, 1968. In addition, five samples were collected on December 14, 1967. A total of seventy-five one-gallon samples was collected and shipped to SWRHL for analysis.

The analysis of the one-gallon milk samples consisted of two procedures: gamma counting and radiochemical analysis for strontium. Upon arrival at SWRHL, three and one-half liters of the sample was gamma scanned for forty minutes. The gamma scan information was processed through a computer program which quantitized the samples for iodine-131, cesium-137, barium-140, and lanthanum-140. After the computer program completed the results, the scan information was examined to ascertain no other radionuclides were present. The strontium analysis consisted of passing one liter of the sample through an ion-exchange resin column which retained the strontium. The strontium, after being eluted from the column, was precipitated as a carbonate compound and was counted after weighing and again one week later. The strontium-89 and 90 activity concentrations were solved by simultaneous equations.

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[1] Additional information on increased levels can be found in: "Radiation Alert Network, December 1967, PHS; Radiological Health Data and Reports; Volume 9, Number 4, April 1968, page 226.

The milk sampling results for periods 1 and 2 are summarized in Table II. No milk samples were taken following the GB-2R redrill (Period 3) since all radioiodines had decayed below significant levels.

WATER SURVEILLANCE

Water sampling coverage during the pre-shot and post-shot periods was provided by a network of thirty-four sampling stations, shown in Figure 5. Fifteen of the sampling locations were within 20 miles of ground zero at open and well water sources and thirteen of the locations were the same as the family milk cow sampling stations. Six of the network locations were municipal water systems located approximately 120 miles from ground zero.

One-gallon water samples were collected on the same schedule as milk samples prior to the GB-2R redrill. Seven samples were collected during and immediately following the GB-2R redrill. All samples were sent to SWRHL for analysis. Upon arrival at SWRHL, three and one-half liters of the sample were gamma scanned for 40 minutes. This information was run through a computer program which routinely calculates values for the following isotopes:

cerium-praseodymium-144
iodine-131
ruthenium-106
cesium-137
zirconium-niobium-95
manganese-54
barium-lanthanum-140
potassium-40

If it had been determined that additional analysis for other radionuclides was necessary, a different set of isotopes could have been specified. No samples required this. After the gamma scan, 250 milliliters of the sample was evaporated and the residue counted for gross alpha and beta. If the gross

beta activity was greater than 10 pCi/l at time of counting, a strontium analysis would have been performed; if the gross alpha were greater than 3 pCi/l, a radium-226 analysis would have been done. None of the samples required this additional analysis.

Water sampling results for periods 1 and 2 are summarized in Table III and are given for period 3 in Table IV. The samples taken during the pre-shot and post-shot periods (periods 1 and 2) were treated routinely as samples are from all Nevada Test Site operations. The samples taken following the GB-2R redrill (period 3), however, were taken specifically for tritium analysis; beta and alpha counting was not done and all gamma spectra were negligible.

PERSONNEL SURVEILLANCE

A network of thermoluminescent dosimeters (TLD's) and film badges was established surrounding the Gasbuggy site. The network consisted of fifty stations located at approximately 1-1/2 mile intervals along existing roads and highways, as shown in Figure 6.

The background radiation level for the network area was established prior to the shot with stations consisting of three dedosed TLD's set out on October 17, 1967, and exchanged on November 15, 1967. They were exchanged again on December 8, 1967, two days before the shot, for three dedosed TLD's and two film badges.

The TLD's used were EG&G Model TL-12 thermoluminescent CaF_2:Mn dosimeters (sensitivity range of 4 mR to 5,000 R) and the two film badges were DuPont Type 545 film badges (sensitivity range of 30 mR to 3 R). Since there was no venting upon detonation, the TLD's and film badges set out December 8, 1967, were left in the field throughout the GB-ER drill-back which began immediately after the shot. The GB-ER drill-back was completed on January 10, 1968, and the TLD's and film badges were returned to SWRHL for analysis.

An entirely different TLD network was established for the GB-2R redrill and GB-ER flaring operation. TLD's were stationed around the site area at 19 locations ranging from 0.1 to six miles from ground zero. Three TLD's were placed at each location on June 27, 1968, and collected on July 16, 1968. The locations are shown in Figure 6. The station locations were selected with regard to prominent wind direction during this period of the year. During daytime hours, the wind is primarily from the southwest. A stable condition generally exists during the nighttime hours when the air 'drains' downhill toward the northwest. A network was placed 1.5 miles northwest of ground zero covering an arc from approximately 345 degrees to 180 degrees and a network crossing the valley through which the drainage winds pass.

The results of the TLD network during periods 1 and 2 are shown graphically in Figure 7. The graph shows the average exposure recorded by the TLD stations located within 15-degree arcs. Table V gives the results of the less extensive TLD network used for period 3. Since the locations of most of the stations and the length of exposure for the two networks were not the same, a direct comparison of the results should not be made.

NATURAL GAS SURVEILLANCE

The PHS provided surveillance of radioactivity in the natural gas produced in the area surrounding the Gasbuggy site. This program consisted of an analysis for fresh fission products and natural radionuclides of the natural gas collected pre-shot and post-shot from all the wells and the gathering system located within five miles of ground zero.

Fifteen samples were analyzed before the detonation to determine background radioactivity levels and thirty-one samples were analyzed after the detonation to check for increased levels of radiation. The results of these samples are given in Table VI. In addition to the samples collected within five miles of ground zero, twelve samples were collected at more distant locations within the El Paso Natural Gas Company's system. The results of these samples are given in Table VII. All samples were analyzed for radioisotopes of xenon and krypton, and the nuclides of radon-222, carbon-14, and

tritium. The analysis of the gas samples showed no evidence of fresh fission products in any sample. Detectable levels of radon-222 were found in both pre and post-shot samples but did not exceed background levels previously reported.[2]

As of June 1, 1969, all producing gas wells within a five-mile radius of ground zero are still physically cut from the El Paso Natural Gas Company's distribution system. Plans for sampling gas on a periodic basis from these producing wells when they are returned to the distribution system are presently being considered by the Atomic Energy Commission.

SUMMARY AND CONCLUSIONS

The first experiment involving the industrial application of the peaceful use of nuclear explosives resulted in no release of radioactive material into the environment at the time of detonation. The Off-Site Radiological Safety Program conducted by the Southwestern Radiological Health Laboratory for the U.S. Atomic Energy Commission documented that no detectable radioactivity was introduced into the off-site environment as a result of the Project Gasbuggy detonation. In addition, the SWRHL was adequately prepared so that personnel could effectuate emergency procedures to insure protection of the public health had an unforeseen accident occurred.

The El Paso Natural Gas Company has not yet resumed production of the wells within a five-mile radius of Gasbuggy. While initial gas samples collected within this area indicate no event-related radioactivity, additional samples will be taken over a period of time to verify the absence of such radioactivity both before and after commercial distribution is effected.

Project Gasbuggy represented no hazard from radioactivity to the population in the vicinity of the detonation site nor has it resulted in the introduction of any device-related radioactivity induced into the existing natural gas distribution system of the El Paso Natural Gas Company.

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[2]For additional information on radon-222 values in gas produced in the San Juan Basin see: Bunce, L.A. and Sattler, F.W.; "Radon-222 in Natural Gas", Radiological Health Data and Reports, Volume 7, Number 8, August 1966; page 441.

FIGURES AND TABLES

		Page
FIGURE 1	Gasbuggy Emplacement Hole and Well Locations	11
FIGURE 2	Gasbuggy Predicted Underground Effects	12
FIGURE 3	Gasbuggy Air Surveillance Network	13
FIGURE 4	Gasbuggy Milk Surveillance Network	14
FIGURE 5	Gasbuggy Water Surveillance Network	15
FIGURE 6	Gasbuggy Thermoluminescent Dosimeter Stations	16
FIGURE 7	Gasbuggy Thermoluminescent Dosimeter Results - Periods 1 and 2	17
TABLE I	Gasbuggy Air Surveillance Network Summary of Beta Activities	18
TABLE II	Gasbuggy Milk Sampling Results Summary - Periods 1 and 2	19
TABLE III	Gasbuggy Water Sampling Results Summary - Periods 1 and 2	20
TABLE IV	Gasbuggy Water Sampling Results - Period 3	21
TABLE V	Gasbuggy Thermoluminescent Dosimeter Results - Period 3	22
TABLE VI	Radon Analysis from Pre- and Post-Shot Natural Gas Sampling	23
TABLE VII	Special Post-Gasbuggy Natural Gas Samples	26

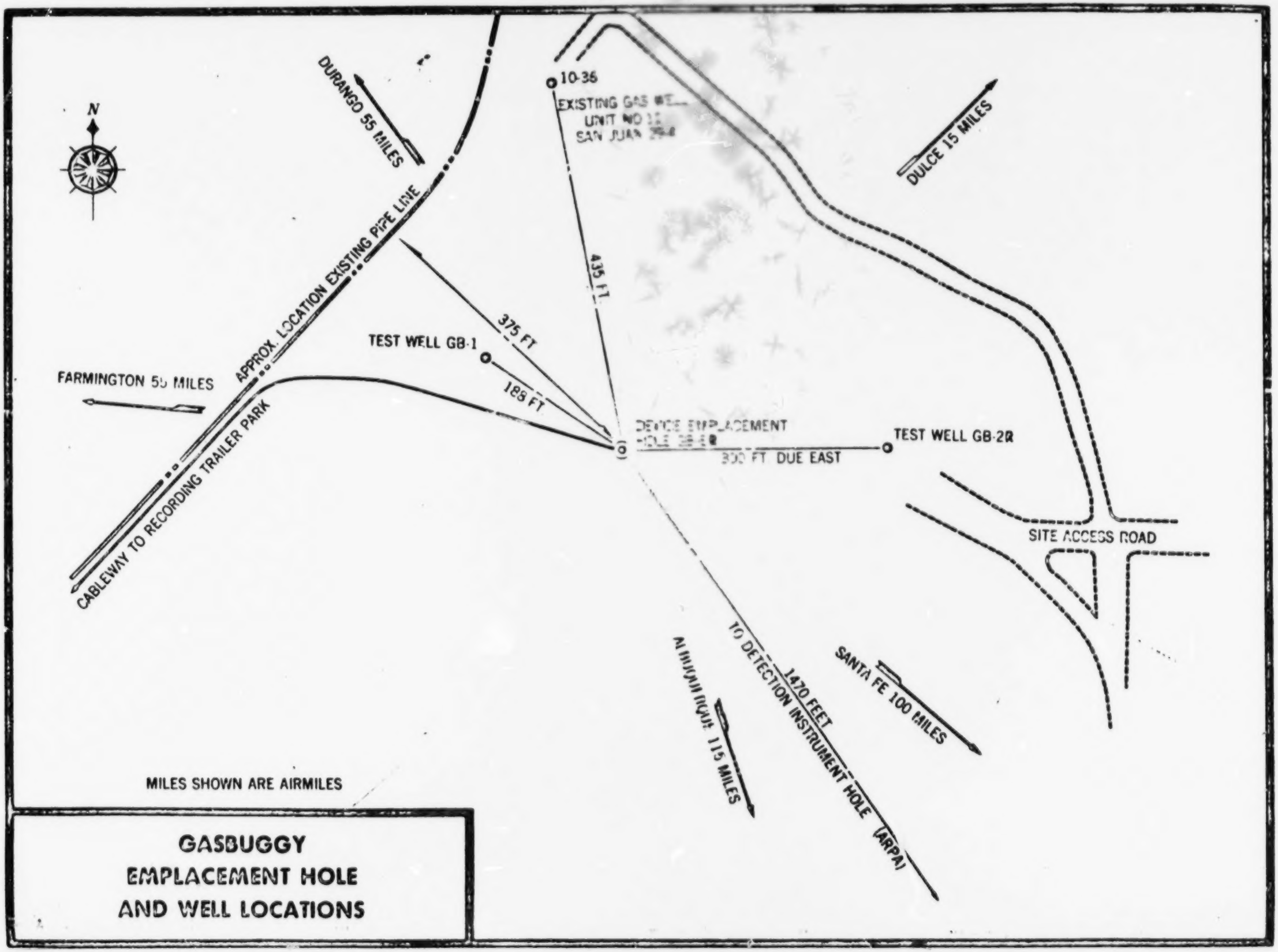
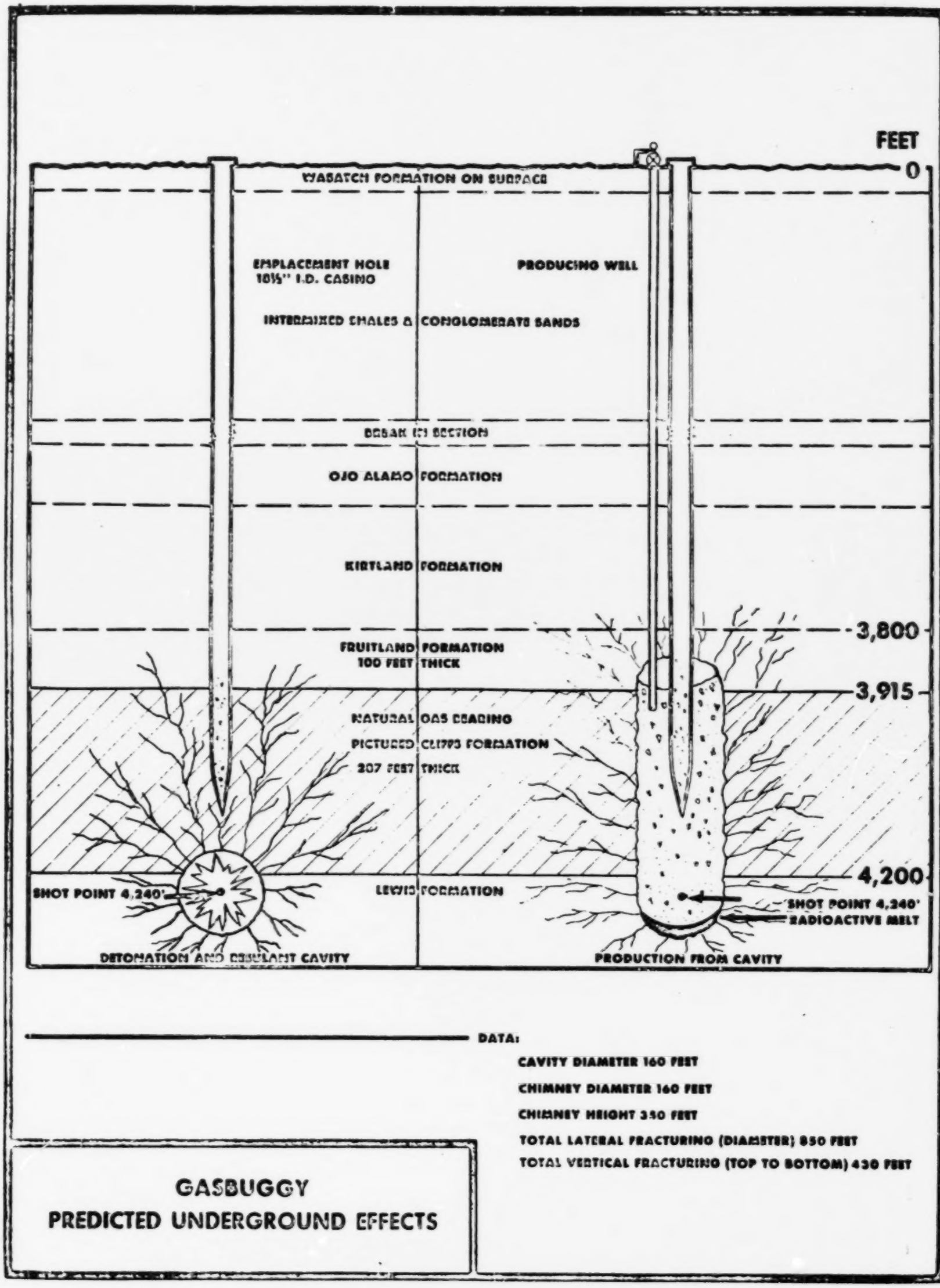

N
DURANGO 55 MILES
10-36
EXISTING GAS WE
UNIT NO 1
SAN JUAN
DULCE 15 MILES
APPROX. LOCATION EXISTING PIPE LINE
435 FT
375 FT
TEST WELL GB-1
188 FT
FARMINGTON 55 MILES
DEVICE EMPLACEMENT
HOLE
TEST WELL GB-2R
300 FT DUE EAST
CABLEWAY TO RECORDING TRAILER PARK
SITE ACCESS ROAD
1470 FEET
TO DETECTION INSTRUMENT HOLE (ARPA)
SANTA FE 100 MILES
115 MILES
MILES SHOWN ARE AIRMILES
GASBUGGY
EMPLACEMENT HOLE
AND WELL LOCATIONS

FIGURE 1



DATA:

CAVITY DIAMETER 160 FEET

CHIMNEY DIAMETER 160 FEET

CHIMNEY HEIGHT 350 FEET

TOTAL LATERAL FRACTURING (DIAMETER) 850 FEET

TOTAL VERTICAL FRACTURING (TOP TO BOTTOM) 430 FEET

GASBUGGY
PREDICTED UNDERGROUND EFFECTS

FIGURE 2

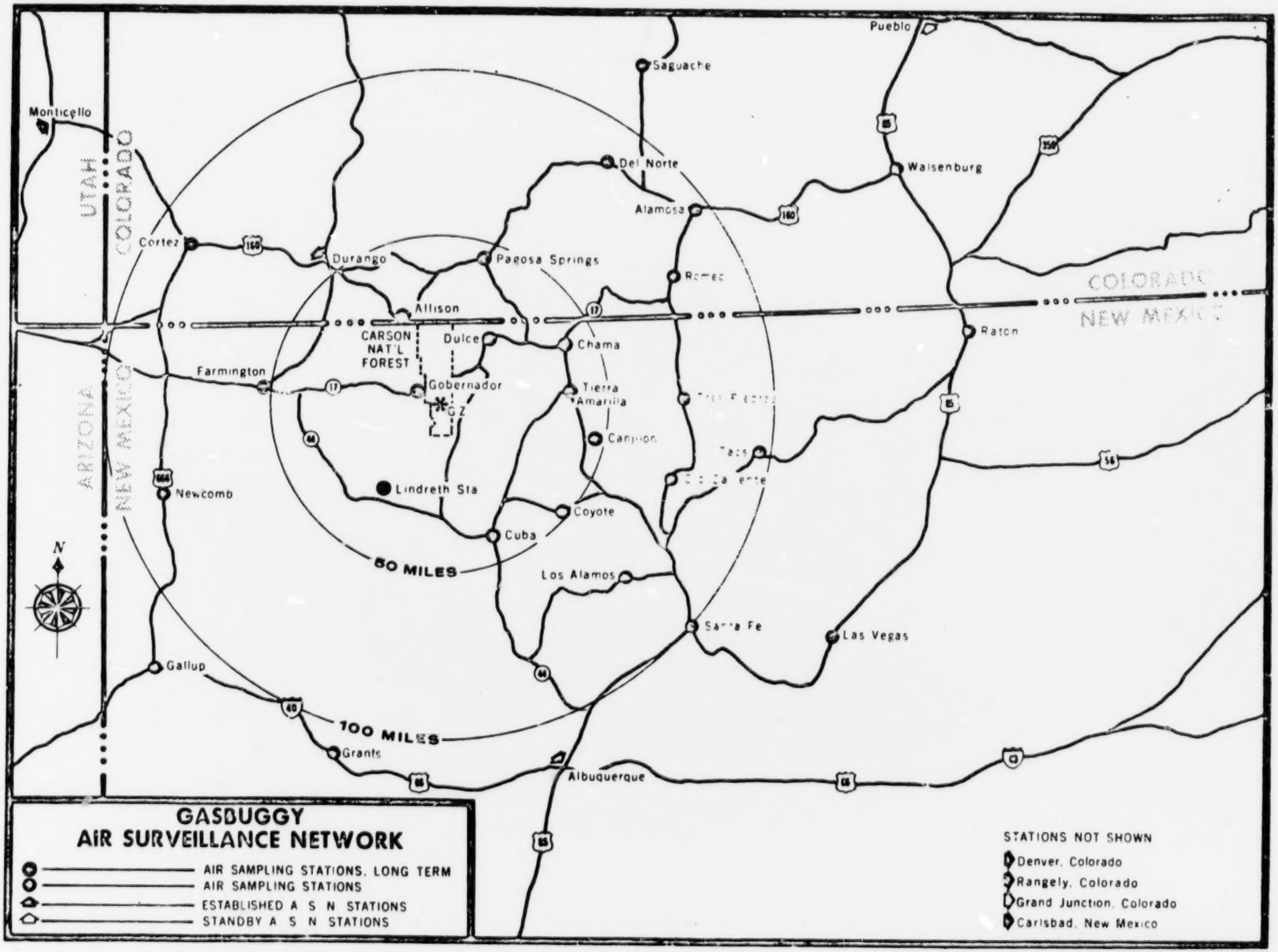
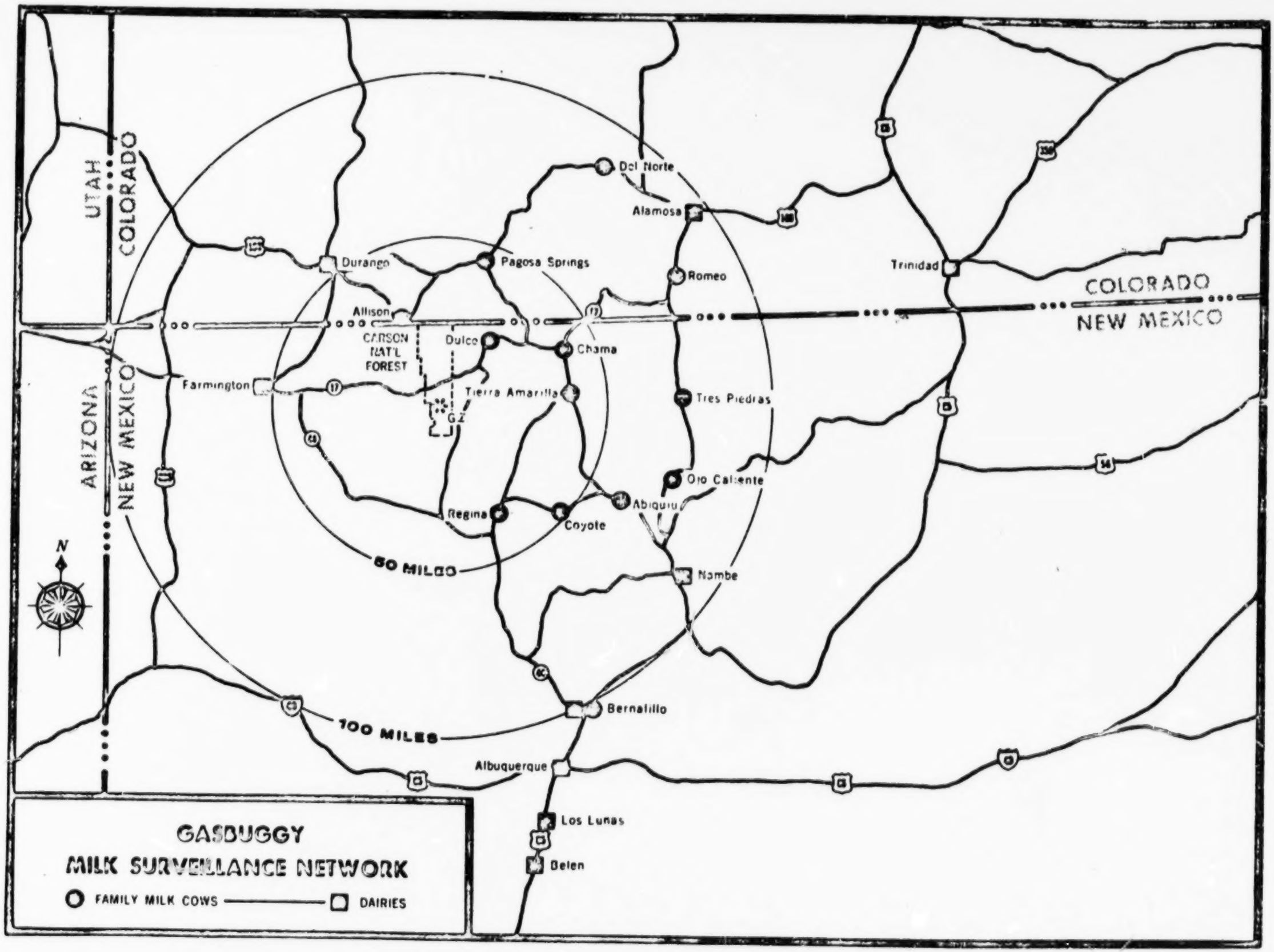
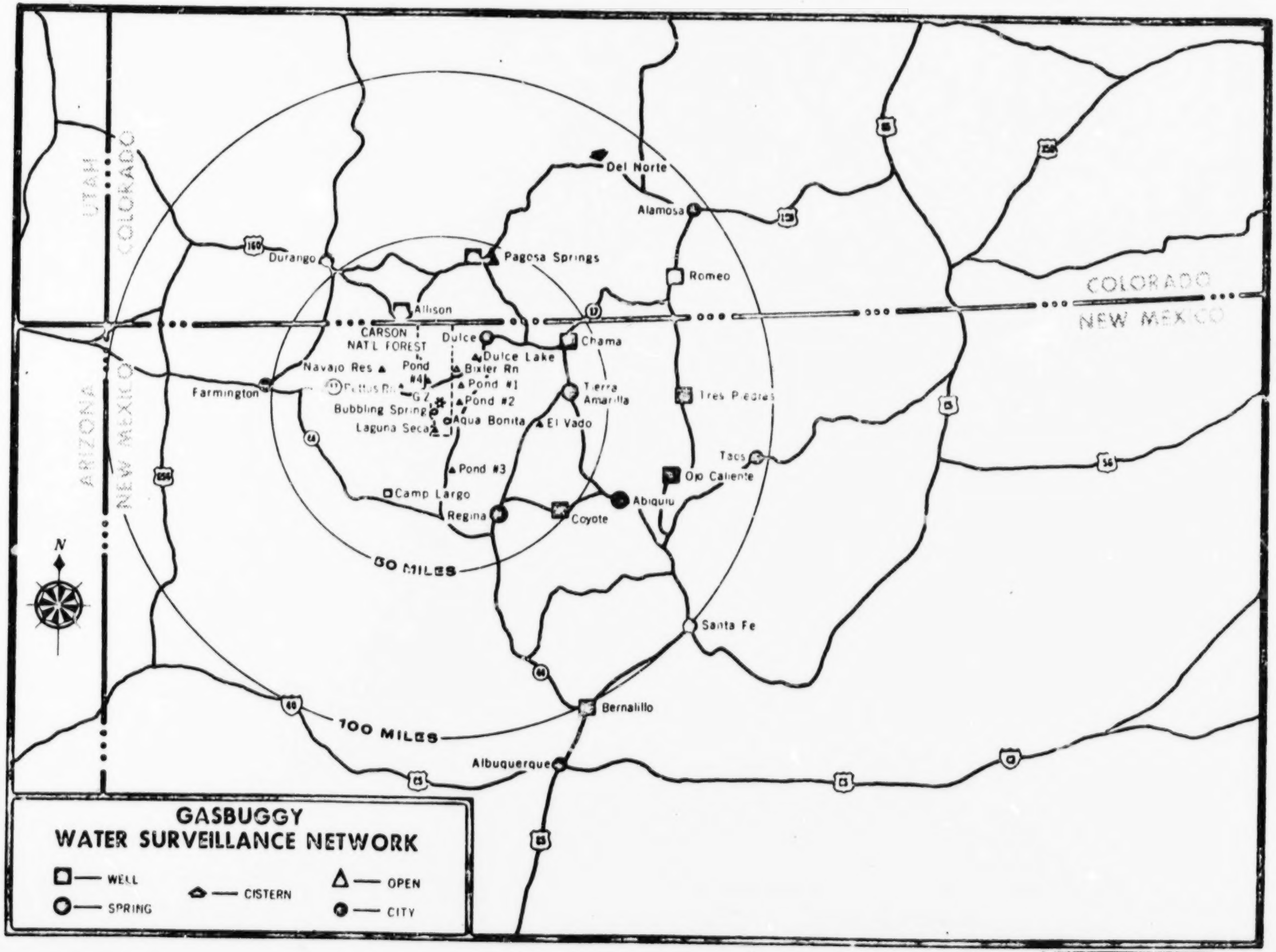

Pueblo
Saguache
Monticello
UTAH
COLORADO
Del Norte
Walsenburg
Alamosa
Cortez
Durango
Pagosa Springs
Romeo
COLORADO
NEW MEXICO
Allison
CARSON NAT'L FOREST
Dulce
Chama
Raton
Farmington
Gobernador
Tierra Amarilla
ARIZONA
NEW MEXICO
Canjilon
Newcomb
Lindreth Sta
Coyote
Cuba
50 MILES
Los Alamos
Santa Fe
Las Vegas
Gallup
100 MILES
Grants
Albuquerque
N
GASBUGGY
AIR SURVEILLANCE NETWORK
AIR SAMPLING STATIONS, LONG TERM
AIR SAMPLING STATIONS
ESTABLISHED A S N STATIONS
STANDBY A S N STATIONS
STATIONS NOT SHOWN
Denver, Colorado
Rangely, Colorado
Grand Junction, Colorado
Carlsbad, New Mexico

FIGURE 3

FIGURE 4


UTAH
COLORADO
ARIZONA
NEW MEXICO
Del Norte
Alamosa
Durango
Pagosa Springs
Romeo
Trinidad
COLORADO
NEW MEXICO
Allison
CARSON NAT'L FOREST
Dulce
Chama
Farmington
Tierra Amarilla
GZ
Tres Piedras
Ojo Caliente
Abiquiu
Regina
Coyote
50 MILES
Nambe
N
Bernalillo
100 MILES
Albuquerque
Los Lunas
Belen
GASBUGGY
MILK SURVEILLANCE NETWORK
FAMILY MILK COWS
DAIRIES


ARIZONA
UTAH
NEW MEXICO
COLORADO
COLORADO
NEW MEXICO
Del Norte
Alamosa
Durango
Pagosa Springs
Romeo
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CARSON
NAT'L FOREST
Dulce
Chama
Dulce Lake
Navajo Res
Pond #4
Bixler Rn
Pond #1
Pond #2
Farmington
Bubbling Spring
Laguna Seca
Aqua Bonita
El Vado
Tierra Amarilla
Tres Piedras
Taos
Ojo Caliente
Pond #3
Camp Largo
Regina
Coyote
Abiquiu
50 MILES
Santa Fe
Bernalillo
100 MILES
Albuquerque
N
GASBUGGY
WATER SURVEILLANCE NETWORK
WELL
SPRING
CISTERN
OPEN
CITY

FIGURE 5

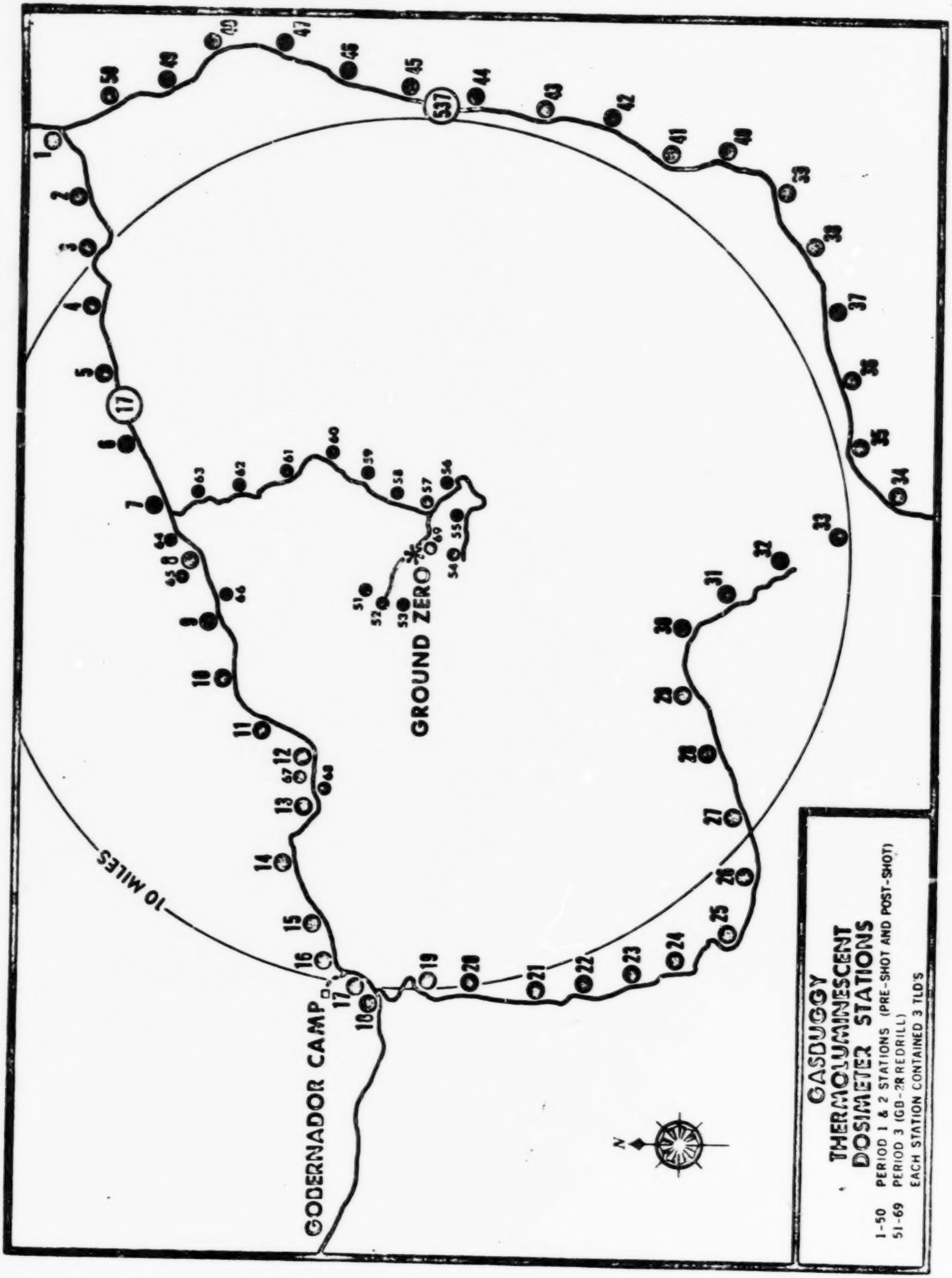
GROUND ZERO
GOBERNADOR CAMP
10 MILES
N
CASDUGGY
THERMOLUMINESCENT
DOSIMETER STATIONS
1-50 PERIOD 1 & 2 STATIONS (PRE-SHOT AND POST-SHOT)
51-69 PERIOD 3 (GB-2R REDRILL)
EACH STATION CONTAINED 3 TLD'S

FIGURE 6

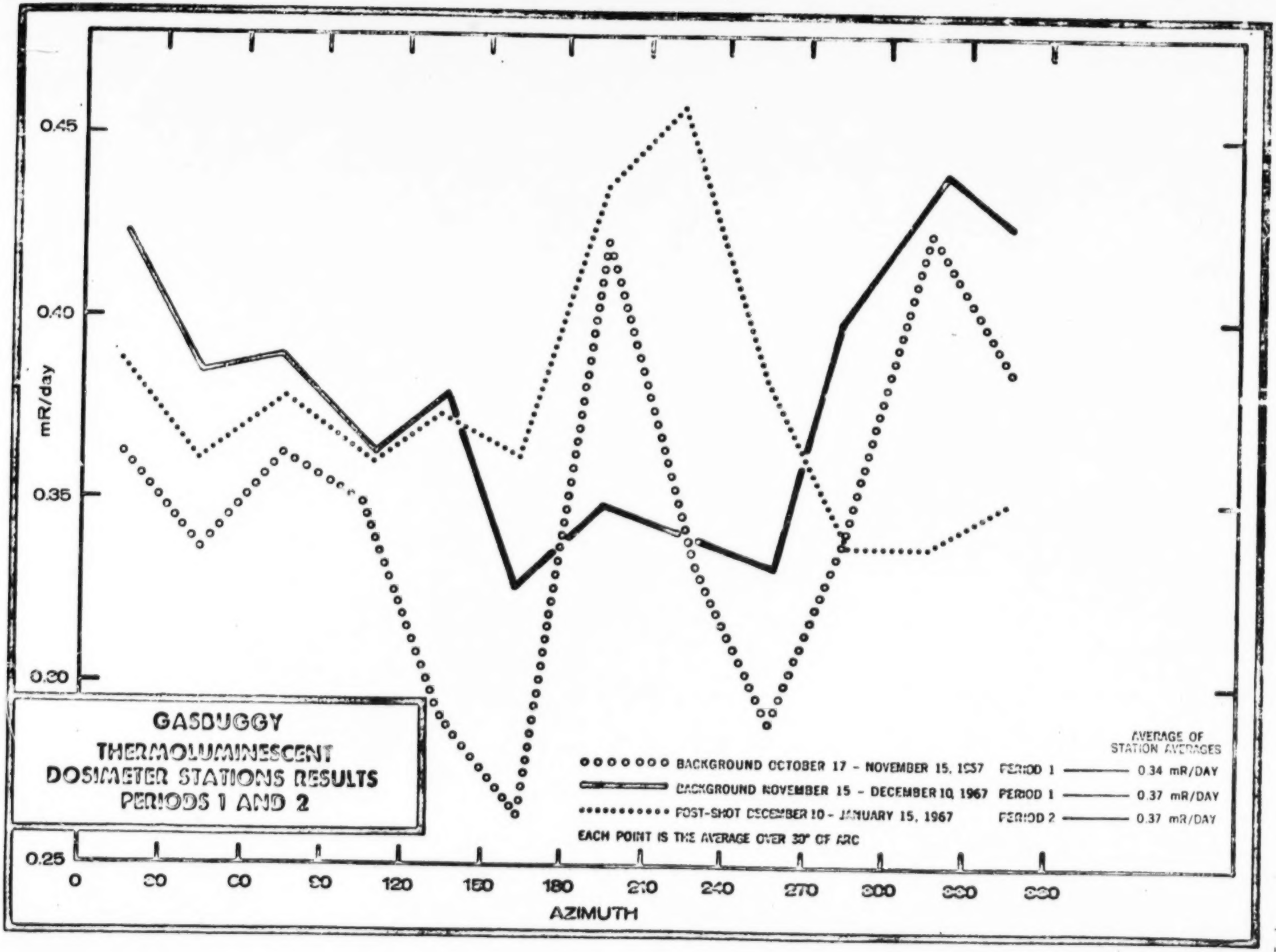
0.45
0.40
mR/day
0.35
0.30
0.25
0
30
60
90
120
150
180
210
240
270
300
330
360
AZIMUTH
GASBUGGY
THERMOLUMINESCENT
DOSIMETER STATIONS RESULTS
PERIODS 1 AND 2
BACKGROUND OCTOBER 17 - NOVEMBER 15, 1967
BACKGROUND NOVEMBER 15 - DECEMBER 10, 1967
POST-SHOT DECEMBER 10 - JANUARY 15, 1967
EACH POINT IS THE AVERAGE OVER 30° OF ARC
AVERAGE OF STATION AVERAGES
PERIOD 1 — 0.34 mR/DAY
PERIOD 1 — 0.37 mR/DAY
PERIOD 2 — 0.37 mR/DAY

FIGURE 7

TABLE I

GASBUGGY AIR SURVEILLANCE NETWORK SUMMARY OF BETA ACTIVITIES[1]

PERIOD	NUMBER OF STATIONS OPERATING	NUMBER OF SAMPLES TAKEN	NUMBER OF SAMPLES ABOVE DETECTABLE LIMITS	RANGE (pCi/m^3) (min)	(max)	AVERAGE OF SAMPLES ABOVE DETECTABLE LIMITS (pCi/m^3)	AVERAGE OF ALL SAMPLES (pCi/m^3)
PERIOD 1 - PRE-SHOT							
11-27-67 to 12-09-67	35	404	80	0.1	1.3	0.2	ND[2]
PERIOD 2 - POST-SHOT							
12-10-67 to 12-24-67	35 or 12[3]	240	27	0.1	0.3	0.1	ND
12-25-67 to 1-19-68	12 or 25[4]	371	336	0.1	7.8	1.0	0.9
Selected ASN Stations[5]							
12-25-67 to 1-19-68	5	105	63	0.1	9.5	0.8	0.5
PERIOD 3 - GB-2 REDRILL							
6-13-68 to 7-18-68	10	200	190	0.1	1.0	0.2	0.2

[1] Gamma analysis results, none of which showed activities above background, are available from SWRHL.

[2] ND - Nondetectable - Detectable Limit: Beta 0.1 pCi/m^3, based on 300 m^3 and 2 minute counting time.

[3] 12-10-67 to 12-13-67: 35 stations operated. 12-13-67 to 12-24-67: 12 stations operated

[4] 1-12-67 to 1-11-68: 12 stations operated. 1-11-68 to 1-19-68: 25 stations operated

[5] Selected ASN Stations:

STATION	STATION NO.
Minneapolis	65
Berkeley	49
Seattle	50
Phoenix	43
New Orleans	92

These scattered stations were selected to show the increased activity was wide spread.

TABLE II

GASBUGGY MILK ANALYSIS RESULTS SUMMARY
PERIODS 1 AND 2

ISOTOPE	NUMBER OF SAMPLES ANALYZED	NUMBER OF SAMPLES ABOVE DETECTABLE LIMIT	RANGE (pCi/l) (min)	(max)	AVERAGE OF SAMPLES ABOVE DETECTABLE LIMIT (pCi/l)	AVERAGE OF ALL SAMPLES (pCi/l)
PRE-SHOT						
^{131}I	52	0	--	--	--	ND
^{137}Cs	52	6	10	34	20	ND
^{89}Sr	30	4	5	5	5	ND
^{90}Sr	30	29	3	18	6	6
POST-SHOT						
^{131}I	23	0	--	--	--	ND
^{137}Cs	23	1	16	16	16	ND
^{89}Sr	20	2	5	5	5	ND
^{90}Sr	20	18	2	8	5	4

ND - Nondetectable

Detectable Limits:
^{131}I 10 pCi/l - based on 3500 ml sample counted for 40 minutes
^{137}Cs 10 pCi/l - based on 3500 ml sample counted for 40 minutes
^{89}Sr 5 pCi/l - based on 1 liter sample counted for 50 minutes
^{90}Sr 2 pCi/l - based on 1 liter sample counted for 50 minutes

TABLE III

GASBUGGY WATER ANALYSIS RESULTS SUMMARY*

ACTIVITY	NUMBER OF SAMPLES COUNTED	NUMBER OF SAMPLES ABOVE DETECTABLE LIMIT	RANGE (pCi/l) (min)	(max)	AVERAGE OF SAMPLES ABOVE DETECTABLE LIMIT (pCi/l)	AVERAGE OF ALL SAMPLES (pCi/l)
PRE-SHOT						
Beta	76	52	2	40	8	5
Alpha	76	25	1	23	4	1
POST-SHOT						
Beta	25	14	2	29	9	5
Alpha	25	7	1	16	3	1

*All water samples had negligible gamma scans

Detectable Limits: Beta - 2 pCi/l - based on 250 ml sample counted for 50 minutes

Alpha - 1 pCi/l - based on 250 ml sample counted for 50 minutes

TABLE IV

GASBUGGY WATER SAMPLING RESULTS - PERIOD 3[1]

DATE TAKEN	SAMPLE LOCATION	TRITIUM[2] (pCi/l)	GAMMA SCAN
6/24/68	Pettus Ranch		Negligible
6/27/68	NS[3] - Drilling Water Pond, Gasbuggy Road and NM 17 (2 mi N of Pond #1)		Negligible
7/16/68	Well and Pond #1	900	Negligible
7/16/68	Pond #4	700	Negligible
7/16/68	Drilling Water Pond	<400	Negligible
7/16/68	NS - Pond (2 mi SE of Laguna Seca)	800	Negligible
7/16/68	Laguna Seca	<400	Negligible

[1]Period 3 - GB-2R Redrill and GB-ER and GB-2R Flaring Operation

[2]Alpha and Beta counts were not made on these 7 samples. The tritium activities given are considered to be background.

[3]NS - Not Shown in Figure 5.

TABLE V

GASBUGGY THERMOLUMINESCENT DOSIMETER RESULTS - PERIOD 3[1]

STATION NO.[2]	AVERAGE DAILY EXPOSURE	STATION NO.	AVERAGE DAILY EXPOSURE
51	0.28 mR	62	0.14 mR
52	0.28 mR	63	0.25 mR
53	0.23 mR	64	0.27 mR
54	0.19 mR	65	0.28 mR
55	0.28 mR	66	0.27 mR
56	0.27 mR	67	0.28 mR
57	0.34 mR	68	0.25 mR
58	0.27 mR	69	0.27 mR
59	0.25 mR	Project Officer	0.22 mR
60	0.27 mR	Controls - Farmington[3]	0.27 mR
61	0.25 mR		

[1]The actual period of exposure was June 27, 1968, to July 16, 1968.

[2]The station locations are given in Figure 6.

[3]These dosimeters remained in Farmington to provide a comparative background for the period.

TABLE VI

RADON ANALYSES FROM GASBUGGY
PRE- AND POST-SHOT NATURAL GAS SAMPLING

WELL	FORMATION[1]	AZIMUTH FROM GZ	DISTANCE FROM GZ	DATE COLLECTED	Rn-222[2] pCi/ft^3
Pre-Shot Samples[3]					
S.J. 28-4 No. 26	MV	255°	5.15 mi	9/19/67	1068
S.J. 28-4 No. 26	MV	255°	5.15 mi	10/24/67	1084
S.J. 28-4 No. 26	MV	255°	5.15 mi	11/14/67	1034
S.J. 29-4 No. 2	PC	274°	1.03 mi	9/19/67	298
S.J. 29-4 No. 2	PC	274°	1.03 mi	10/16/67	(4)
S.J. 30-4 No. 4[5]	PC	348°	8.54 mi	9/19/67	(4)
S.J. 30-4 No. 4	PC	348°	8.54 mi	10/24/67	(4)
Indian E No. 1	PC	63°	1.27 mi	9/19/67	(4)
Indian E No. 1	PC	63°	1.27 mi	10/16/67	493
Indian E No. 1	PC	63°	1.27 mi	11/21/67	470
Indian H No. 1[6]	PC	128°	4.70 mi	9/19/67	179
Indian H No. 1	MV	128°	4.70 mi	10/03/67	309
Indian H No. 1	PC	128°	4.70 mi	10/24/67	199
Indian H No. 1	MV	128°	4.70 mi	10/24/67	354
Indian H No. 1	PC	128°	4.70 mi	11/07/67	204
Post-Shot Samples[3]					
S.J. 27-4 No. 1	MV	179°	5.40 mi	1/02/68	34
S.J. 27-4 No. 1	MV	179°	5.40 mi	1/30/68	9
S.J. 28-4 No. 1	MV	260°	4.40 mi	12/27/67	520
S.J. 28-4 No. 2	MV	251°	4.07 mi	12/27/67	146
S.J. 28-4 No. 6	PC	218°	0.59 mi	2/27/68	288
S.J. 28-4 No. 7	PC	126°	2.14 mi	2/27/68	239
S.J. 28-4 No. 8	MV	178°	4.56 mi	1/30/68	1028
S.J. 28-4 No. 13	MV	136°	4.60 mi	12/26/67	1165
S.J. 28-4 No. 14	MV	228°	4.50 mi	12/27/67	230
S.J. 28-4 No. 16	MV	235°	5.30 mi	12/26/67	859
S.J. 28-4 No. 17	MV	240°	3.88 mi	12/26/67	754

WELL	FORMATION[1]	AZIMUTH FROM GZ	DISTANCE FROM GZ	DATE COLLECTED	Rn-222[2] pCi/ft^3
Post-Shot Samples[3] - cont					
S.J. 28-4 No. 26	MV	255°	5.15 mi	12/20/67	1628
S.J. 28-4 No. 27	MV	243°	5.45 mi	12/26/67	1080
S.J. 28-4 No. 28	MV	246°	4.79 mi	12/26/67	70
S.J. 29-4 No. 1	MV	282°	5.12 mi	12/20/67	79
S.J. 29-4 No. 2	PC	274°	1.03 mi	2/27/68	302
S.J. 29-4 No. 4	PC	309°	0.84 mi	2/27/68	464
S.J. 29-4 No. 10[7]	PC	344°	0.10 mi	No Sample Taken	
S.J. 29-4 No. 14	MV	277°	4.45 mi	12/27/67	34
S.J. 29-4 No. 16	PC	39°	0.72 mi	2/27/68	483
S.J. 29-4 No. 18	MV	280°	2.49 mi	12/26/67	592
S.J. 30-4 No. 4[5]	PC	348°	8.54 mi	12/12/67	333
Indian A No. 2	PC	43°	1.28 mi	12/27/67	480
Indian E No. 1	PC	63°	1.27 mi	12/27/67	52
Indian I No. 1[6]	MV	139°	5.65 mi	12/19/67	617
Indian I No. 1	PC	139°	5.65 mi	12/19/67	761
Indian I No. 1	PC	139°	5.65 mi	1/30/68	9
Indian B No. 1	MV	136°	4.58 mi	12/19/67	216
Indian L No. 2	MV	129°	3.96 mi	1/02/68	18
Indian H No. 1	PC	128°	4.70 mi	12/19/67	244
Indian H No. 1	MV	128°	4.70 mi	12/19/67	484
S.J. 28-4 No. 21	MV	265°	4.93 mi	12/27/67	634

[1] Gas bearing formation: MV is Mesa Verde formation, PC is Pictured Cliffs formation.

[2] The minimum level of detection (MLD) for radon-222 is 1 pCi/ft^3. Similarly MLS's for other isotopes analyzed are:

Xenons	- 200 pCi/ft^3
Kryptons	- 200 pCi/ft^3
Carbon-14	- 300 pCi/ft^3
Tritium	- 20 pCi/ft^3

All radon-222 values have been corrected for decay to the time of sample collection.

[3] The table only contains concentrations for radon-222. The samples were also analyzed for radioxenons, radiokryptons, carbon-14, and tritium. Results of these analyses were all below the minimum detectable levels shown in Footnote 2. All radons on pre-shot samples were analyzed at the field laboratory in Farmington. All post-shot radon analyses were performed in Las Vegas. The Farmington analyses were carried out on raw natural gas while the Las Vegas analyses were made by separating the radon from the natural gas. The Las Vegas results have been corrected by an appropriate correction factor to make them comparable to the pre-shot Farmington results.

[4] These samples were not analyzed for radon-222, but were analyzed for xenons and kryptons.

[5] This well is located outside of the area bounded by a 5-mile radius from ground surface zero.

[6] Samples from Indian H No. 1 and Indian I No. 1 wells can be taken from one or both the Pictured Cliffs (PC) and Mesa Verde (MV) formations because these wells penetrate both formations.

[7] This well is also called 10-36 and is located 435 feet from ground zero. It was stemmed prior to the event and could not be sampled post-shot.

TABLE VII

SPECIAL POST-GASBUGGY NATURAL GAS SAMPLES

SAMPLE DESCRIPTION	COLLECTION DATE 1968	AVERAGE OF 3 ANALYSES ^{222}Rn in pCi/ft^3*
Mainline, blockvalve 3-mile post 36+	4/24	260
Same	4/24	404
24" Main and loop blockvalve 2	4/24	475
24" Main, blockvalve 2	4/24	713
S.J. 29-5 Unit 45 22 MD-R.A. Mesa Verde	4/25	1005
S.J. 28-5 Unit 55 R.A. Mesa Verde	4/25	1132
S.J. 28-5 Unit 45 R.A. Dakota	4/25	275
S.J. 28-5 Unit 19 R.A. Picture Cliff	4/25	484
S.J. 27-4 Unit 13 R.A. Picture Cliff	4/25	761**
S.J. 30-4 Unit 4 R.A. Picture Cliff	4/25	405
Ehrenberg Meter Station	4/26	164
Topok Meter Station	4/26	294

*Corrected for decay to the time of sample collection

**Duplicate analysis

NOTE: Each sample was analyzed for ^{3}H, ^{14}C, radioxenon, and radiokrypton. No activity was detected above minimum detectable levels of 20, 300, 200, and 200 pCi/ft^3, respectively.